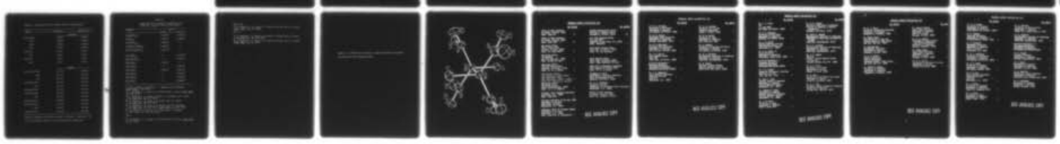
AD-A051 684 PRINCETON UNIV N J DEPT OF CHEMISTRY F/G 7/2
THE MOLYBDENUM-TO-MOLYBDENUM TRIPLE BOND. 5. PREPARATION AND ST--ETC(U)
MAR 78 M H CHISHOLM, F A COTTON, M W EXTINE N00014-76-C-0826
UNCLASSIFIED TR-78-09 NL

| OF |
AD
A051684



END
DATE
FILMED
4-78
DDC

OFFICE OF NAVAL RESEARCH

Contract N00014-76-C-0826

Task No. NR -56-625

TECHNICAL REPORT NO. 78-09

The Molybdenum-to-Molybdenum Triple Bond. 5. Preparation and Structure of Dimethyltetrakis(dimethylamido)dimolybdenum.

by M. H. Chisholm[1], F. A. Cotton[2], M. W. Extine[2]
and C. A. Murillo[1]

Departments of Chemistry

[1]Princeton University,

Princeton, New Jersey 08540

and

[2]Texas A & M University,

College Station, Texas 77843

Prepared for Publication
in
Inorganic Chemistry

March 8, 1978

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER 6	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) The Molybdenum-to-Molybdenum Triple Bond. 5. Preparation and Structure of Dimethyltetrakis(dimethylamido)dimolybdenum.		5. TYPE OF REPORT & PERIOD COVERED 9 Technical Report, 1978
		6. PERFORMING ORG. REPORT NUMBER 14 TR-78-09
7. AUTHOR(s) 10 M. H. Chisholm, F. A. Cotton, M. W. Extine and C. A. Murillo		8. CONTRACT OR GRANT NUMBER(s) 15 N00014-76-C-0826 NR 056-625
9. PERFORMING ORGANIZATION NAME AND ADDRESS Department of Chemistry Princeton University Princeton, N. J. 08540		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS 11 8 Mar 78
11. CONTROLLING OFFICE NAME AND ADDRESS Office of Naval Research Department of the Navy		12. REPORT DATE March 8, 1978
		13. NUMBER OF PAGES 15 12 17p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report)
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Metal-to-Metal Multiple Bonds, Molybdenum.

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The reaction of $Mo_2Cl_2(NMe_2)_4$ with methyllithium affords $Mo_2Me_2(MNe_2)_4$, an air-sensitive, yellow crystalline compound. This new compound has been structurally characterized by x-ray crystallography. The crystals are monoclinic, space group $P2_1/c$, with unit cell dimensions of a = 15.342(2)Å, b = 13.578(2)Å, c = 8.264(1)Å, β = 97.26(1)°, V = 1707.7(4)Å^3 and Z = 4. The asymetric unit consists of two independent dinuclear molecules each lying at a crystallographic center of symmetry. The two molecules are virtually identical and each one has

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE
S/N 0102-LF-014-6601

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

400 363 JOB

virtual C_{2h} symmetry, consistent with a anti rotameric conformation. The following mean distances, averaged over all crystallographically independent ones assuming C_{2h} symmetry in each molecule are: Mo-Mo, 2.201(1)Å; Mo-C, 2.175(6)Å; Mo-N, 1.954(5)Å.

Submitted to Inorg. Chem.

Contribution from the Departments of Chemistry,
Princeton University, Princeton, N. J. 08540, and
Texas A&M University, College Station, Texas 77843

The Molybdenum-to-Molybdenum Triple Bond. 5. Preparation and Structure of Dimethyltetrakis(dimethylamido)dimolybdenum.[1]

M. H. Chisholm,*[2a] F. A. Cotton,*[2b] M. W. Extine[2b] and C. A. Murillo[2a]

ABSTRACT

The reaction of $Mo_2Cl_2(NMe_2)_4$ with methyllithium affords $Mo_2Me_2(MNe_2)_4$, an air-sensitive, yellow crystalline compound. This new compound has been structurally characterized by x-ray crystallography. The crystals are monoclinic, space group $P2_1/c$, with unit cell dimensions of a = 15.342(2)Å b = 13.578(2)Å, c = 8.264(1)Å, β = 97.26(1)°, V = 1707.7(4)Å^3 and Z = 4. The asymmetric unit consists of two independent dinuclear molecules each lying at a crystallographic center of symmetry. The two molecules are virtually identical and each one has virtual C_{2h} symmetry, consistent with a anti rotameric conformation. The following mean distances, averaged over all crystallographically independent ones assuming C_{2h} symmetry in each molecule are: Mo-Mo, 2.201(1)Å; Mo-C, 2.175(6)Å; Mo-N, 1.954(5)Å.

INTRODUCTION

The existence of an extensive chemistry centering around the triply-bonded Mo-Mo and W-W units is now well established and has recently been reviewed.[3,4] A firm structural base for interpreting this chemistry has been provided by more than a score of x-ray crystallographic structure determinations. Among these, however, there have been only a few pairs of molybdenum and tungsten compounds with the same or very similar sets of ligands. The comparisons afforded by such pairs are valuable in developing the comparative chemistry of the M-M multiple bonds in the 2nd and 3rd transition series.

To further this structural basis we report here the preparation and structural characterization of dimethyltetrakis(dimethylamido)dimolybdenum, $Mo_2Me_2(NMe_2)_4$. The structure may be compared to that of the close ditungsten analog, $W_2Me_2(NEt_2)_4$, the structure of which has already been reported.[5] The preparation of this new compound was accomplished by taking advantage of our recently published route[6] to substitution products of the readily available $Mo_2(NMe_2)_6$, viz., reaction (1), and then replacing Cl by methyl by means of the methyllithium reagent, reaction (2). At a later time we

$$Mo_2(NMe_2)_6 + 2\ Me_3SiCl \rightarrow Mo_2Cl_2(NMe_2)_4 + 2\ Me_3SiNMe_2 \qquad (1)$$

$$Mo_2Cl_2(NMe_2)_4 + 2\ MeLi \rightarrow Mo_2Me_2(NMe_2)_4 + 2\ LiCl \qquad (2)$$

shall report further studies of reactions of type 2 which have also allowed the isolation of alkyls, such as $M_2Et_2(NMe_2)_4$, for which β-H elimination is not impossible.

RESULTS AND DISCUSSION

Synthesis. - The compounds $M_2Cl_2(NMe_2)_4$, where M = Mo and W, react with ether and tetrahydrofuran: reaction 2 was carried out in toluene. $Mo_2Me_2(NMe_2)_4$ was isolated from 2 as a yellow, crystalline, diamagnetic, air-sensitive compound in greater than 70% yield. It is thermally stable and may be sublimed at 100°C, 10^{-2} torr. In the mass spectrometer a molecular ion, $Mo_2Me_2(NMe_2)_4^+$ together with many other Mo_2-containing ions were observed. Ir, nmr and analytical data are recorded in the Experimental Section.

Structural Results. - $Mo_2(NMe_2)_4Me_2$ is isostructural to $M_2(NMe_2)_4Cl_2$. The asymmetric unit consists of one half of each of two independent dinuclear molecules, each molecule having crystallographically imposed C_i symmetry deviates only slightly from C_{2h}. Atomic thermal and positional parameters are given in Table 1. An ORTEP of molecule 1 is shown in Figure 1. Bond distances and angles are given in Table 2. The atom labelling scheme used for molecule II parallels that used for molecule I with Mo(2), N(3)-N(4), and C(7)-C(12) replacing Mo(1), N(1)-N(2), and C(1)-C(6), respectively.

Discussion of Structure. - The crystal structure of $Mo_2(NMe_2)_4Me_2$ is closely similar to those[6] of $Mo_2(NMe_2)_4Cl_2$ and $W_2(NMe_2)_4Cl_2$. In all of these, the presence of four molecules in a unit cell belonging to the space group $P2_1/c$ does not correspond, as is usually the case, to the molecule being the asymmetric unit, with the four molecules then being related by the two types of crystallographic inversion center at 0,0,0 and 1/2,0,1/2. In these structures the asymmetric unit is composed of halves of two different molecules. This means that there are two crystallographically independent molecules, each type located on a crystallographic center of inversion. However, as Table II shows, the differences between the two molecules of $Mo_2(NMe_2)_4Me_2$ are completely insignificant, not only chemically but terms of the statistical validity of the differences.

The structure takes the form of the anti rotamer, as has been the case in every $M_2(NR_2)_4X_2$ structure so far examined. The Mo-Mo distance is entirely typical for $Mo\overset{3^\circ}{—}Mo$ bonds in compounds of this class, as Table III makes clear. The mean Mo-N distance, 1.954(5)Å, is not significantly different from those found in other structures of the $Mo_2(NR_2)_{6-n}X_n$ type, which have always been in the range 1.94-1.97Å. It is interesting that once again the Mo-X and W-X distances in molecules where n = 2 are practically identical. Thus, for example, in the two $M_2(NMe_2)_4Cl_2$ molecules[6] the Mo-Cl and W-Cl distances are 2.348(5)Å and 2.329(5)Å. The Mo-C distance found here, 2.175(6)Å, is indistinguishable from that in $W_2Me_2(NEt_2)_4$, namely 2.171(11)Å.

EXPERIMENTAL SECTION

General chemical procedures and the preparation of $Mo_2Cl_2(NMe_2)_4$ have been described previously.[6]

Preparation. - Methyllithium (8.34 mmol) in ether (4.53 mL) was placed in a dried, round-bottom flask (100 mL) under a nitrogen atmosphere. The ether was removed *in vacuo*. The resulting white solids (MeLi) and $MoCl_2(NMe_2)_4$ (4.17 mmol) were then dissolved in toluene (40 mL). The solution so formed was initially cooled to *ca*. 0°C (ice-bath) for 1/2 h and then warmed to room temperature for 1 1/2 h with stirring. The solvent was stirred and the solids dried at 25°C, 10^{-2} torr for 1 h. Hexane (40 mL) was added and the solution was filtered under a nitrogen atmosphere using standard Schlenk techniques. The yellow filtrate was collected, reduced in volume to *ca* 8 mL, and coded to *ca*. -10°C, yielding a yellow crystalline product $Mo_2Me_2(NMe_2)_4$ (1.20 g; 73% yield based on eq. 2), which was collected by filtration and dried in vacuum (25°C, 10^{-2} torr). Anal. Calcd for $C_{10}H_{30}N_4Mo_2$: C, 30.16; H, 7.59; N, 14.07. Found: C, 29.9; M, 7.46; N, 13.8. ^1H nmr data, 60 MHz, 40°C, toluene-d_8 solvent: δ(Me) = 1.17, $\delta(NMe_2)$ = 3.29 (δ in ppm rel TMS). Ir data, nujol mull, CsI plates (1500-200 cm^{-1} region): (1422(w), 1310(w), 1242(m), 1172(w), 1150(m), 1122(w), 1042(m), 952(s), 940(vs), 590(m), 500(s), 335(m,br).

X-Ray Crystallography. - A crystal of $Mo_2(NMe_2)_4Me_2$ measuring *ca*. 0.2 x 0.25 x 0.4 mm was mounted in a thin-walled glass capillary embedded in epoxy resin with the major crystal axis nearly coincident with the ϕ axis of the goniometer. Crystal quality was checked with ω-scans of several intense low-angle reflections which had peak widths at half-height of *ca*. 0.2°. Cell constants and axial photographs indicated that the crystal belonged to the monoclinic system with a = 15.342(2)Å, b = 13.578(2)Å, c = 8.264(1)Å, β = 97.26(1)°, V = 1707.7(4)$Å^3$. The observed volume is consistent with that expected for Z = 4.

Data were collected at 22±2°C on a Syntex P$\bar{1}$ autodiffractometer equipped with a graphite crystal monochromator in the incident beam and using MoKα (λ = 0.710730Å) radiation. The θ-2θ scan technique was used with scans ranging from 1.1° above and 1.1° below the calculated Kα_1, Kα_2 doublet, variable scan speeds of from 4.0 to 24.0°/min and with a scan to background time ratio of 2.0. The intensities of three standard reflections were monitored frequently throughout data collection and showed no decrease in intensity. The integrated intensities of 2240 unique, non-systematically absent reflections having 0°<2θ<45° were recorded. The data were reduced to a set of relative $|F_o|^2$ values and were not corrected for absorption (μ = 14.3 cm^{-1}). The 1716 reflections having $|F_o|^2 > 3\sigma(|F_o|^2)$ were used in subsequent structure solution and refinement. Systematic absences on 0k0 (k=2n+1) and h0ℓ (ℓ = 2n+1) uniquely determined the space group to be $P2_1/c$ (No. 14).

Since the cell constants of $Mo_2(NMe_2)_4Me_2$ were very similar to those of $Mo_2(NMe_2)_4Cl_2$ and both compounds crystallized in the same space group, the starting atomic positions for $Mo_2(NMe_2)_4Me_2$ were taken from the $Mo_2(NMe_2)_4Cl_2$ structure,[6] assuming Mo-Me = Mo-Cl. The positions were sufficiently close to allow refinement to proceed smoothly to convergence. In the final stages of refinement anisotropic thermal parameters were used for all atoms. The final unweighted and weighted residuals were R_1 = 0.037 and R_2 = 0.060, respectively. A value of 0.07 was used for p in the calculation of the weights. The esd of an observation of unit weight was 1.412. The largest peaks in a final difference Fourier map were about where some methyl-group hydrogen atoms might be expected, but no attempt was made to introduce or refine these.

A table of observed and calculated structure factor tables (3 pages) is available as supplementary material. Ordering instructions will be found on any current masthead page.

Acknowledgements

We thank the Office of Naval Research for support of this work at Princeton University and the National Science Foundation for support at Texas A&M University.

REFERENCES

1. Part 4; M. H. Chisholm, F. A. Cotton, M. W. Extine and W. W. Reichert, J. Amer. Chem. Soc., 100 xxxx (1978).

2. (a) Princeton University. (b) Texas A&M University.

3. M. H. Chisholm and F. A. Cotton, Accts. Chem. Research, 11, xxx (1978).

4. F. A. Cotton, Accts Chem. Research, 11, xxx (1978).

5. M. H. Chisholm, F. A. Cotton, M. W. Extine, M. Millar, and B. R. Stults, Inorg. Chem., 15, 2244 (1976).

6. M. Akiyama, M. H. Chisholm, F. A. Cotton, M. W. Extine, and C. A. Murillo, Inorg. Chem., 16, 2407 (1977).

Table I. POSITIONAL AND THERMAL PARAMETERS AND THEIR ESTIMATED STANDARD DEVIATIONS.[a]

Atom	X	Y	Z	β_{11}	β_{22}	β_{33}	β_{12}	β_{13}	β_{23}
Mo(1)	0.45070(4)	0.05707(5)	0.46198(8)	0.00292(3)	0.00341(3)	0.0109(1)	0.00098(5)	0.00134(9	0.0007(1)
Mo(2)	-0.02775(4)	0.07171(5)	0.02880(8)	0.00299(3)	0.00361(3)	0.0128(1)	-0.00063(5)	0.00145(10	-0.0014(1)
N(1)	0.3605(4)	0.0385(5)	0.6069(8)	0.0031(3)	0.0058(4)	0.014(1)	-0.0002(6)	0.001(1)	-0.001(1)
N(2)	0.5181(5)	0.1797(5)	0.4644(8)	0.0049(4)	0.0040(4)	0.015(1)	0.0001(6)	0.001(1)	0.001(1)
N(3)	0.0732(5)	0.1602(5)	0.0640(9)	0.0050(4)	0.0039(4)	0.018(1)	-0.0020(6)	0.001(1)	-0.003(1)
N(4)	-0.1224(4)	0.0931(5)	-0.1481(8)	0.0030(3)	0.0054(4)	0.014(1)	-0.0002(6)	-0.002(1)	-0.000(1)
C(1)	0.4037(5)	0.0110(7)	0.214(1)	0.0039(4)	0.0066(6)	0.012(1)	-0.0004(8)	-0.002(1)	-0.002(1)
C(2)	-0.0798(6)	0.0370(7)	0.255(1)	0.0050(5)	0.0076(6)	0.016(1)	0.0008(9)	0.007(1)	-0.001(2)
C(3)	0.3548(6)	-0.0209(8)	0.752(1)	0.0049(5)	0.0084(6)	0.018(2)	0.0003(10)	0.006(1)	0.008(2)
C(4)	0.2888(6)	0.1139(7)	0.590(1)	0.0032(4)	0.0077(6)	0.023(2)	0.0032(8)	0.001(1)	-0.005(2)
C(5)	0.6087(6)	0.2072(7)	0.523(1)	0.0049(5)	0.0065(6)	0.022(2)	-0.0034(9)	0.000(2)	-0.001(2)
C(6)	0.4637(7)	0.2666(7)	0.424(1)	0.0087(6)	0.0039(5)	0.029(2)	0.0039(10)	0.006(2)	0.005(2)
C(7)	0.1688(6)	0.1489(8)	0.050(1)	0.0032(4)	0.0080(7)	0.026(2)	-0.0034(8)	0.003(1)	-0.000(2)
C(8)	0.0523(7)	0.2645(7)	0.086(1)	0.0072(6)	0.0040(5)	0.030(2)	-0.0014(9)	-0.001(2)	-0.005(2)
C(9)	-0.1507(6)	0.0454(8)	-0.306(1)	0.0054(5)	0.0078(6)	0.017(2)	0.0013(10)	-0.002(2)	-0.004(2)
C(10)	-0.1733(6)	0.1866(7)	-0.134(1)	0.0055(5)	0.0065(6)	0.028(2)	0.0033(9)	0.001(2)	-0.000(2)

[a] THE FORM OF THE ANISOTROPIC THERMAL PARAMETER IS: $\exp[-(\beta_{11}h^2 + \beta_{22}k^2 + \beta_{33}\ell^2 + \beta_{12}hk + \beta_{13}h\ell + \beta_{23}k\ell)]$.

TABLE II. Bond Distances (Å) and Angles (Deg) for $Mo_2(NMe_2)_4Me_2$.[a]

Atoms	Molecule I	Molecule II
	Distances	
Mo(1)-Mo(1)'	2.201(1)	2.201(1)
-N(1)	1.958(6)	1.952(6)
-N(2)	1.959(6)	1.948(6)
-C(1)	2.173(7)	2.176(8)
N(1)-C(3)	1.46(1)	1.49(1)
-C(4)	1.50(1)	1.47(1)
N(2)-C(5)	1.46(1)	1.47(1)
-C(6)	1.46(1)	1.50(1)
	Angles	
Mo(1)'-Mo(1)-N(1)	104.4(2)	104.8(2)
-N(2)	104.7(2)	104.0(2)
-C(1)	101.6(2)	100.9(2)
N(1)-Mo(1)-N(2)	121.1(2)	121.4(3)
-C(1)	111.3(3)	112.1(3)
N(2)-Mo(1)-C(1)	111.5(3)	111.0(3)
Mo(1)-N(1)-C(3)	134.0(5)	133.9(5)
-C(4)	115.1(5)	115.5(5)
C(3)-N(1)-C(4)	109.6(6)	109.9(6)
Mo(1)-N(2)-C(5)	134.4(5)	135.1(5)
-C(6)	113.5(5)	114.5(5)
C(5)-N(2)-C(6)	111.2(7)	110.0(6)

[a]Atoms are labelled as shown for Molecule I in Figure 1. Molecules I and II lie on inversion centers at 1/2,0,1/2 and 0,0,0, respectively.

TABLE III

Lengths of M-M Triple Bonds in Compounds of the Types M_2L_6, $M_2L_4X_2$ and Some of their Adducts

Compound	M-M, Å M = Mo	M = W
$M_2(CH_2SiMe_3)_6$	2.167(?)[a]	2.255(2)[b]
$M_2(NMe_2)_6$	2.214(3)[c]	2.294(2)[d]
$M_2(OCH_2CMe_3)_6$	2.222(2)[e]	---
$M_2(OSiMe_3)_6(NHMe_2)_2$	2.242(1)[f]	---
$M_2(OBu^t)_4(O_2COBu^t)_2$	2.241(1)[g]	---
$M_2(O_2CNMe_2)_6$	---	2.279(1)[h]
$M_2Me_2(O_2CNEt_2)_4$	---	2.272(1)[h]
$M_2Me_2(NMe_2)_4$	2.201(1)[i]	---
$M_2Me_2(NEt_2)_4$	---	2.291(1)[j]
$M_2Cl_2(NMe_2)_4$	2.201(2)[k]	2.285(2)[k]
$M_2Cl_2(NEt_2)_4$	---	2.301(1)[l]
$M_2Br_2(NEt_2)_4$	---	2.301(2)[m]
$M_2I_2(NEt_2)_4$	---	2.300(4)[m]

[a] F. Huq, W. Mowat, A. Shortland, A. C. Skapski, and G. Wilkinson, Chem. Commun., 1079 (1971).

[b] M. H. Chisholm, F. A. Cotton, M. W. Extine and B. R. Stults, Inorg. Chem., 15, 2252 (1976).

[c] M. H. Chisholm, F. A. Cotton, B. Frenz, W. W. Reichert, and L. Shive, J. Am. Chem. Soc., 98, 4469 (1976).

[d] M. H. Chisholm, F. A. Cotton, M. W. Extine, and B. R. Stults, J. Am. Chem. Soc., 98, 4477 (1976).

[e] M. H. Chisholm, F. A. Cotton, C. A. Murillo, and W. W. Reichert, J. Am. Chem. Soc., 99, 1652 (1977); Inorg. Chem., 16, 1801 (1977).

[f] M. H. Chisholm, F. A. Cotton, M. W. Extine and W. W. Reichert, J. Amer. Chem. Soc., 100, 153 (1978).

[g] Ref. 1.

[h] M. H. Chisholm, F. A. Cotton, M. W. Extine, and B. R. Stults, Inorg. Chem., 16, 603 (1977).

[i]This work.

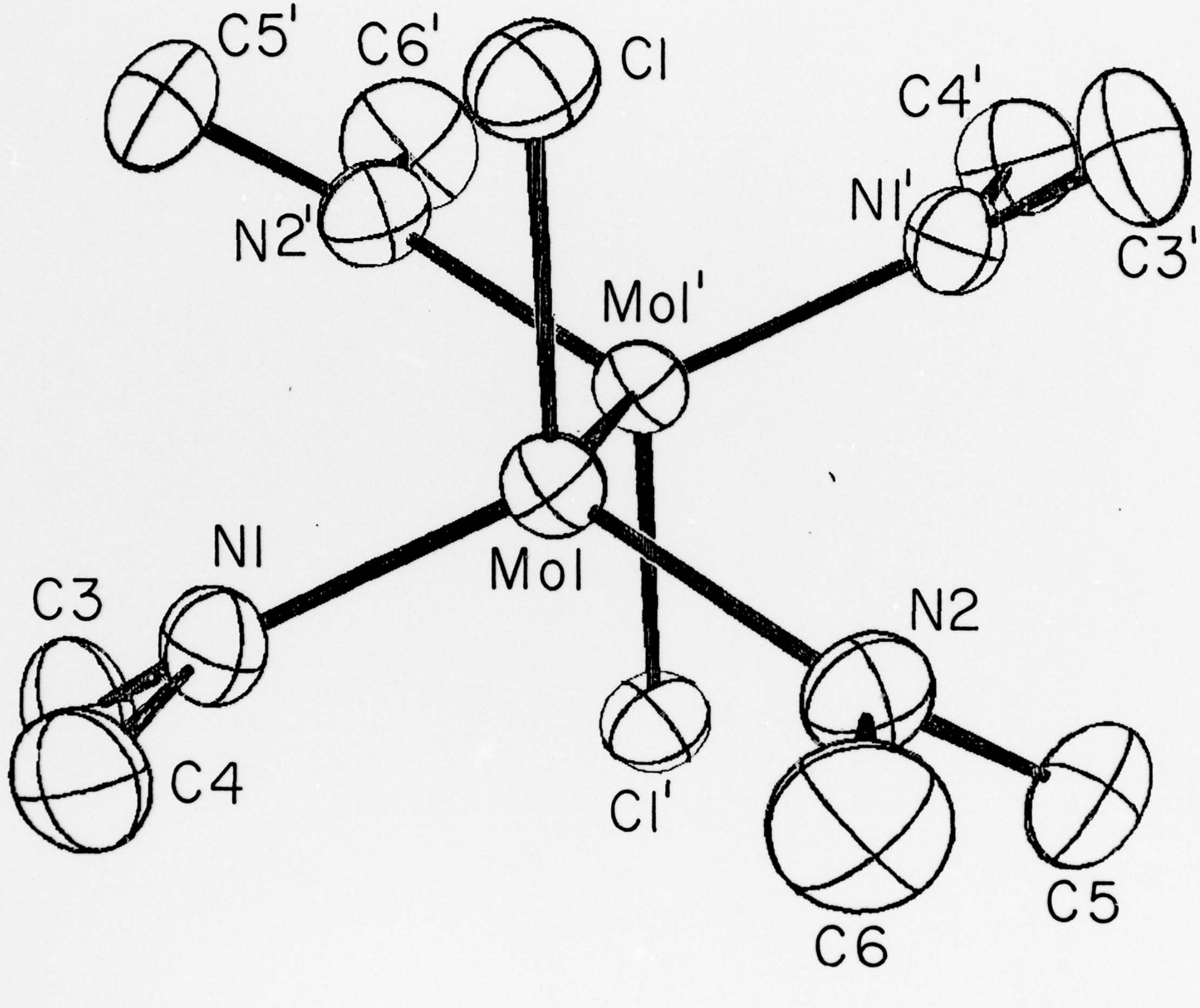
[j]M. H. Chisholm, F. A. Cotton, M. W. Extine, M. Millar, and B. R. Stults, Inorg. Chem., 15, 2244 (1976).

[k]Ref. 6.

[l]M. H. Chisholm, F. A. Cotton, M. W. Extine, M. Millar and B. R. Stults, J. Am. Chem. Soc., 98, 4486 (1976).

[m]M. H. Chisholm, F. A. Cotton, M. W. Extine, M. Millar, and B. R. Stults, Inorg. Chem., 16, 320 (1977).

Figure 1. An ORTEP view of Molecule I using 50% probability ellipsoids and showing the atom labelling scheme.


C5'
C6'
Cl
C4'
N2'
N1'
C3'
Mo1'
N1
C3
Mo1
N2
C4
Cl'
C5
C6

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies
Office of Naval Research Arlington, Virginia 22217 Attn: Code 472	2
Office of Naval Research Arlington, Virginia 22217 Attn: Code 102IP I	6
ONR Branch Office 536 S. Clark Street Chicago, Illinois 60605 Attn: Dr. Jerry Smith	1
ONR Branch Office 715 Broadway New York, New York 10003 Attn: Scientific Dept.	1
ONR Branch Office 1030 East Green Street Pasadena, California 91106 Attn: Dr. R. J. Marcus	1
ONR Branch Office San Francisco Area Office One Hallidie Plaza San Francisco, Calif. 94102 Attn: Dr. Phillip A. Miller	1
ONR Branch Office 495 Summer Street Boston, Massachusetts 02210 Attn: Dr. L. H. Peebles	1
Director, Naval Research Laboratory Washington, D.C. 20390 Attn: Code 6100	1
The Asst. Secretary of the Navy (R&D) Department of the Navy Room 4E736, Pentagon Washington, D.C. 20350	1
Commander, Naval Air Systems Command Department of the Navy Washington, D.C. 20360 Attn: Code 310C (H. Rosenwasser)	1

	No. Copies
Defense Documentation Center Building 5, Cameron Station Alexandria, Virginia 22314	12
U.S. Army Research Office P.O. Box 12211 Research Triangle Park, N.C. 27709 Attn: CRD-AA-IP	1
Naval Ocean Systems Center San Diego, California 92152 Attn: Mr. Joe McCartney	1
Naval Weapons Center China Lake, California 93555 Attn: Head, Chemistry Division	1
Naval Civil Engineering Laboratory Port Hueneme, California 93041 Attn: Mr. W. S. Haynes	1
Professor O. Heinz Department of Physics & Chemistry Naval Postgraduate School Monterey, California 93940	1
Dr. A. L. Slafkosky Scientific Advisor Commandant of the Marine Corps (Code RD-1) Washington, D.C. 20380	1
Office of Naval Research Arlington, Virginia 22217 Attn: Dr. Richard S. Miller	1

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies
Dr. M. A. El-Sayed University of California Department of Chemistry Los Angeles, California 90024	1
Dr. M. W. Windsor Washington State University Department of Chemistry Pullman, Washington 99163	1
Dr. E. R. Bernstein Colorado State University Department of Chemistry Fort Collins, Colorado 80521	1
Dr. C. A. Heller Naval Weapons Center Code 6059 China Lake, California 93555	1
~~Dr. M. H. Chisholm~~ ~~Princeton University~~ ~~Department of Chemistry~~ ~~Princeton, New Jersey 08540~~	1
Dr. J. R. MacDonald Naval Research Laboratory Chemistry Division Code 6110 Washington, D.C. 20375	1

	No. Copies
Dr. G. B. Schuster University of Illinois Chemistry Department Urbana, Illinois 61801	1
Dr. E. M. Eyring University of Utah Department of Chemistry Salt Lake City, Utah	1
Dr. A. Adamson University of Southern California Department of Chemistry Los Angeles, California 90007	1
Dr. M. S. Wrighton Massachusetts Institute of Technology Department of Chemistry Cambridge, Massachusetts 02139	1
Dr. M. Rauhut American Cyanamid Company Chemical Research Division Bound Brook, New Jersey 08805	1

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies		No. Copies
Dr. D. A. Vroom IRT P.O. Box 80817 San Diego, California 92138	1	Dr. R. W. Vaughan California Institute of Technology Division of Chemistry & Chemical Engineering Pasadena, California 91125	1
Dr. G. A. Somorjai University of California Department of Chemistry Berkeley, California 94720	1	Dr. Keith H. Johnson Massachusetts Institute of Technology Department of Metallurgy and Materials Science Cambridge, Massachusetts 02139	1
Dr. L. N. Jarvis Surface Chemistry Division 4555 Overlook Avenue, S.W. Washington, D.C. 20375	1	Dr. M. S. Wrighton Massachusetts Institute of Technology Department of Chemistry Cambridge, Massachusetts 02139	1
Dr. W. M. Risen, Jr. Brown University Department of Chemistry Providence, Rhode Island 02912	1	Dr. J. E. Demuth IBM Corp. Thomas J. Watson Research Center P.O. Box 218 Yorktown Heights, New York 10598	1
~~Dr. M. H. Chisholm~~ ~~Princeton University~~ ~~Chemistry Department~~ ~~Princeton, New Jersey 08540~~	1	Dr. C. P. Flynn University of Illinois Department of Physics Urbana, Illinois 61801	1
Dr. J. B. Hudson Rensselaer Polytechnic Institute Materials Division Troy, New York 12181	1	Dr. W. Kohn University of California (San Diego) Department of Physics La Jolla, California 92037	1
Dr. John T. Yates National Bureau of Standards Department of Commerce Surface Chemistry Section Washington, D.C. 20234	1	Dr. R. L. Park Director, Center of Materials Research University of Maryland College Park, Maryland 20742	1
Dr. Theodore E. Madey Department of Commerce National Bureau of Standards Surface Chemistry Section Washington, D.C. 20234	1		
Dr. J. M. White University of Texas Department of Chemistry Austin, Texas 78712	1		

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies
Dr. W. T. Peria Electrical Engineering Department University of Minnesota Minneapolis, Minnesota 55455	1
Dr. Narkis Tzoar City University of New York Convent Avenue at 138th Street New York, New York 10031	1
Dr. Chia-wei Woo Northwestern University Department of Physics Evanston, Illinois 60201	1
Dr. D. C. Mattis Yeshiva University Physics Department Amsterdam Avenue & 185th Street New York, New York 10033	1
Dr. Robert M. Hexter University of Minnesota Department of Chemistry Minneapolis, Minnesota 55455	1
Dr. Leonard Wharton James Franck Institute Department of Chemistry 5640 Ellis Avenue Chicago, Illinois 60637	1
Dr. M. G. Lagally Department of Metallurgical and Mining Engineering University of Wisconsin Madison, Wisconsin 53706	1
Dr. Robert Gomer James Franck Institute Department of Chemistry 5640 Ellis Avenue Chicago, Illinois 60637	1
Dr. R. F. Wallis University of California (Irvine) Department of Physics Irvine, California 92664	1

TECHNICAL REPORT DISTRIBUTION LIST

	No. Copies
Dr. R. M. Grimes University of Virginia Department of Chemistry Charlottesville, Virginia 22901	1
Dr. M. Tsutsui Texas A&M University Department of Chemistry College Station, Texas 77843	1
Dr. C. Quicksall Georgetown University Department of Chemistry 37th & O Streets Washington, D.C. 20007	1
Dr. M. F. Hawthorne University of California Department of Chemistry Los Angeles, California 90024	1
Dr. D. B. Brown University of Vermont Department of Chemistry Burlington, Vermont 05401	1
Dr. W. B. Fox Naval Research Laboratory Chemistry Division Code 6130 Washington, D.C. 20375	1
Dr. J. Adcock University of Tennessee Department of Chemistry Knoxville, Tennessee 37916	1
Dr. A. Cowley University of Texas Department of Chemistry Austin, Texas 78712	1

	No. Copies
Dr. W. Hatfield University of North Carolina Department of Chemistry Chapel Hill, North Carolina 27514	1
Dr. D. Seyferth Massachusetts Institute of Technology Department of Chemistry Cambridge, Massachusetts 02139	1
~~Dr. M. H. Chisholm~~ ~~Princeton University~~ ~~Department of Chemistry~~ ~~Princeton, New Jersey 08540~~	1
Dr. B. Foxman Brandeis University Department of Chemistry Waltham, Massachusetts 02154	1
Dr. T. Marks Northwestern University Department of Chemistry Evanston, Illinois 60201	1
Dr. G. Geoffrey Pennsylvania State University Department of Chemistry University Park, Pennsylvania 16802	1
Dr. J. Zuckerman University of Oklahoma Department of Chemistry Norman, Oklahoma 73019	1